Pearl competition from Asia steps up...

Excerpts from an article by Don Kirkwood, published in Business Queensland, *23/8/93*

Australia's A$ 200–300 m pearl industry could be threatened by competition from Asia if it does not upgrade its techniques, according to Bruce Stevens, managing director of Reefarm Hatcheries. 'We've got to improve our genetic stock', he says. 'We've just collected our stock from the wild. There's been no selective breeding'.

Reefarm hatcheries produce the high-quality boutique pearl, the highest-priced pearl in the world, fetching from A$ 400 to A$ 80,000 each.

He claims that, using techniques developed in Australia, the Indonesian industry is establishing hatcheries, and may well be able to produce higher-grade pearls in future.

He says 'Australian pearl farmers have high labour costs, but hatcheries can produce spat for A$ 3 each, compared with A$ 20 each if they're gathered from the wild.'

The natural pearl shell populations in French Polynesia

Excerpts from Atlas de la Polynésie française *(chapter written by André Intes)*

Past over-harvesting of natural pearl-shell stocks has caused widespread depletion of oyster-producing lagoons at the same time as the development of pearl culture requires increasing quantities of oysters. Studies carried out before 1960 showed a progressive decline in stocks and proposed measures to conserve or rehabilitate this resource. None of these recommendations have been implemented, probably because almost all were based on techniques similar to those used in oyster farming (spat collection, oyster beds, husbandry), in which local communities had no faith.

Only when there was no choice but to consider the resource completely exhausted, and when the initial grafting tests demonstrated the product's high commercial value, the techniques proposed, by the Fisheries Service in particular, were quickly adopted.

Since then, exploitation has undergone a complete transformation, with objectives and techniques being radically changed. Only the targeted resource 'i.e. natural stocks' has remained the same. These are still exploited because controlled breeding tests carried out from 1976 to 1979, and those currently under way, have not yet allowed large-scale production of spat.

In 1983, fishing by skindivers still supplied nearly 80 per cent of oysters for grafting, but this harvesting of adult animals will be eliminated soon. Spat collection, for which effective techniques have been developed both by the Fisheries Service and by the Institute for the Promotion of Aquacultural and Maritime Activities (EVAAM), will become the only supply source for professionals, as in Japanese pearl farming.

Having stated these development prospects, the resource's biology as well as its numerical strength remain incompletely understood and must be more closely studied in order to promote pearl culture. This is a very difficult problem, however, for there are as many stocks as there are lagoons and each one has it own characteristics.

For the moment, the scattered geographic locations of the lagoons makes a Territory-wide assessment impossible, but relatively complete information is available on some stocks, such as the one in Takapoto atoll in the Tuamotu Archipelago. This atoll has always been among the principal pearl-shell production centres. Its maximum annual production has been estimated at about 400 mt. In the 1950s, harvests remained large and exceeded 100 mt during some seasons (1955,1957). During 1982–1983, ORSTOM and EVAAM carried out a study and assessment of this stock. The findings are described below.

Stock distribution

Pearl oysters live in shallow depths of up to 60 m, clinging by their byssus to the coral substrates which form their biotope in the atoll lagoon. In this biotope, abundance varies according to ecological parameters and fishing pressure. These factors determine the distribution of the pearl-shell stocks.

Mean densities, even if they do not allow abundance in the lagoon to be determined absolutely, are a good way of describing stock distribution.

Density measurements

Densities are determined by divers who count oysters along transects. Each strip surveyed by a diver measures 2.5 m in width, i.e. 5 m for a team of two divers. The number of pearl oysters found every 10 m is noted. The typical 50 m long line is considered to be the basic density survey unit and corresponds to a sampling area of 250 m².

Surveys carried out in 1984 over the entire area of the lagoon have allowed density distribution in Takapoto Lagoon to be described in terms of depth and location. Vertically, depth layers or strata 10 m thick were used. Horizontally, there are three fishing zones, with a reserve area making up a fourth, at the southern end of the lagoon.

This two-dimensional division is of practical interest for stock exploitation; legal fishing is carried out by free divers, leaving the more shallow strata more exposed to harvesting. Fishing seasons are opened on a rotational basis in the various areas. The overall results obtained have been expressed in term of mean densities in Table 1.

The reserve area returns the highest densities, especially in the surface layer. In Area 1, the average density gradient increases with depth. The same trend was observed in Areas 2 and 3, especially if the 0–20 m layer is considered as a single unit. It is probable that this gradient inversion between the reserve area and the fishing areas is linked to both legal and illegal harvesting.

The deepest area of the lagoon, with a depth of more than 40 m, is limited to Area 2 and showed only low densities. These trends by area were also found in the other strata, with the highest densities observed between 20 and 40 m, that is to say, for all practical purposes, beyond the reach of most skin divers.

These observations tend to show that the still relatively productive lagoons, either overall or in specific locations, have densities of around one oyster per 10 m².

These average densities allowed Takapoto to be compared with other lagoons where similar studies were carried out between 1982 and 1984, as shown in Table 2.

Table 2: Mean densities of pearl oysters per m² in some French Polynesian atolls

Atoll	Mean density	Standard error
Scilly (Society Islands)	0.10	0.09
Takapoto (Tuamotu Group)	0.09	0.07
Gambier Islands	0.02	0.05
Hikueru (Tuamotu Group)	0.01	0.01
Manihi (Tuamotu Group)	0.01	0.01

Table 1: Densities of pearl oysters per m² and by area depending on depth

Depth	Mean number of oysters per square metre				
	Reserve	Area #1	Area #2	Area #3	Mean
0-10 m	0.24	0.07	0.04	0.03	0.09
10-20 m	0.12	0.08	0.02	0.02	0.06
20-30 m	0.17	0.11	0.07	0.07	0.10
30-40 m	—	0.13	0.14	0.08	0.12
> 40 m	—	—	0.02	—	0.02
Mean	**0.18**	**0.09**	**0.06**	**0.05**	**0.09**

These lagoons are divided into two groups, whose densities vary considerably. The first group (Scilly – Takapoto) recorded one pearl oyster per 10 m², while in the second group (Gambier – Hikueru – Manihi), no more than one or two pearl oyster were observed for every 100m².

In Manihi and Hikueru, the margin of error is very small and corresponds to a relatively uniform stock where all the densities observed were low.

The situation is different in the Gambier Islands, however, because high densities do occur, particularly in the area of Aukena (one pearl oyster per 2 m²), at depths of less than 10 m.

These observations tend to show that lagoons which are still relatively productive sustain densities of around one pearl oyster per 10 m², either overall or in specific locations.

Density is very important for reproduction, because successful spawning depends heavily on the number of gametes released and on simultaneous spawning by the parental stock. These two aspects, called mass effect (the quantity of sexual cells) and group effect (spawning by one animal induces that of its nearest neighbours) are fundamental elements of stock management.

Stock assessment

In addition to the density measurements described above, it is important to know the extent of the pearl oyster biotope in order to estimate the stock's size.

Extent of the biotope

The limited penetration depth of satellite telemetry techniques does not allow all hard lagoon substrates to be surveyed. In contrast, echosounding eliminates bathymetric constraints and permits a sampling effort proportionate to the size of the lagoons surveyed, which can vary from 80 to 300 km². The presence of coral structures shows up the recording as irregularities in the relief and a thicker trace.

In Takapoto, 12 transverse radials were used to estimate the area of the lagoon floor. The area of the biotope favourable to oyster growth represented about 65 per cent of the developed area of the lagoon floor, of 83 km².

This relatively large area should not be surprising, as it is known that more than 400 coral patches and pinnacles rise above the sediment to emerge at high tide and that the number of lesser-sized structures, especially those invisible from the surface, is even greater. The surface area of coral slopes and walls is thus considerable.

Using information on the extent of the biotope and average densities by strata, the stratified sampling technique allows the size of the lagoon population to be calculated (figures are given in Table 3).

Scilly Lagoon in the Society Islands is twice the size of the Takapoto lagoon, and has higher mean densities, but as the biotope is proportionally much less developed, its total population is only 5.5 million specimens compared with 7.5 million in Takapoto.

Table 3: Pearl shell population of Takapoto lagoon

Depth	Pearl shell population				
	Reserve area	Area #1	Area #2	Area #3	Total Lagoon
0 - 10 m	220,000	65,000	65,000	50,000	400,000
10 - 20 m	320,000	435,000	205,000	110,000	1,070,000
20 - 30 m	325,000	1,210,000	800,000	750,000	3,085,000
30 - 40 m		500,000	1,600,000	700,000	2,800,000
> 40 m			122,000		122,000
Total	865,000		2,210,000		2,792,000

Biomass

A regular monthly sampling carried out in Takapoto lagoon over a one-year period allowed the average weight of specimens by size to be calculated (Table 4).

The population's demographic structure was deduced from a series of measurements taken by divers, as depicted in Figure 1.

From a combination of these various approaches, stock biomass can be calculated in three different ways: total wet weight (weight of the shell and soft parts), wet body weight (weight of the wet soft parts) and dry body weight (weight of soft parts after drying).

- Total wet weight: 1,773 mt
- Biomass: 188.5 mt
- Dry weight: 39.5 mt

Characteristics of the population

The growth and mortality parameters were determined from a tagging experiment which commenced in 1983, during Cyclone Veena, and continued until 1987. More than 500 oysters were tagged and periodically checked at seven lagoon stations.

Stainless steel tags were driven into the substrate in the immediate vicinity of the selected animal. This process avoids stressful handling and the animal's growth is not disturbed.

Subsequent measurements are carefully taken by divers, also in order to avoid stress. The data gathered during nine inspections, at intervals ranging

Table 4: Mean length–weight relationships of pearl oysters in Takapoto lagoon

Length	Mean weight (g)		
	Total weight	Biomass	Dry weight
40 mm	5.1	1.4	0.1
50 mm	10.4	2.5	0.3
60 mm	18.6	3.2	0.5
70 mm	30.4	5.7	0.8
80 mm	46.6	7.9	1.2
90 mm	67.8	10.5	1.7
100 mm	94.9	13.6	2.3
110 mm	128.6	17.2	3.1
120 mm	169.7	21.3	4.0
130 mm	219.1	26.0	5.0
140 mm	277.5	31.2	6.3
150 mm	345.8	37.0	7.7
160 mm	424.8	43.3	9.8
170 mm	515.4	50.3	11.3
180 mm	618.5	57.9	13.4
190 mm	734.9	66.2	15.7
200 mm	865.5	75.1	18.3
210 mm	1,011.3	84.7	21.2
220 mm	1,173.0	94.9	24.4

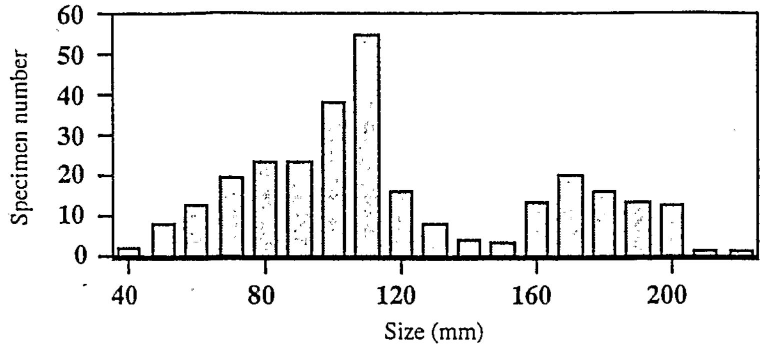

Figure 1: Structure of the pearl–shell population in terms of specimen size

from three months to one year, made it possible to plot a graph of size increases over time and to calculate mortality rates.

Growth

Growth was studied using the von Bertalanffy model:

$$Lt = Lw\ (1 - e^{-k}\ (t - t_o))$$

in which: Lt = Length after time t
Lw = Theoretical length reached at the end of an infinite period
K = A constant value expressing the rate of growth of this species
t_o = Curve origin

Fitting this model to the data observed made it possible to suggest the following mean growth equation: Lt = 206.14 (1 - e $^{-0.264}$ (t + 0.503))

The growth data obtained from the tagging experiment are summarised in the age/size key of Table 5.

If it is considered that the maximum length is the last size significantly recorded in the population, minimum lifespan would be approximately 9.5 years.

Maximum lifespan as calculated from the von Bertalanffy equation parameters, using the Pauly formula, would be approximately 11 years.

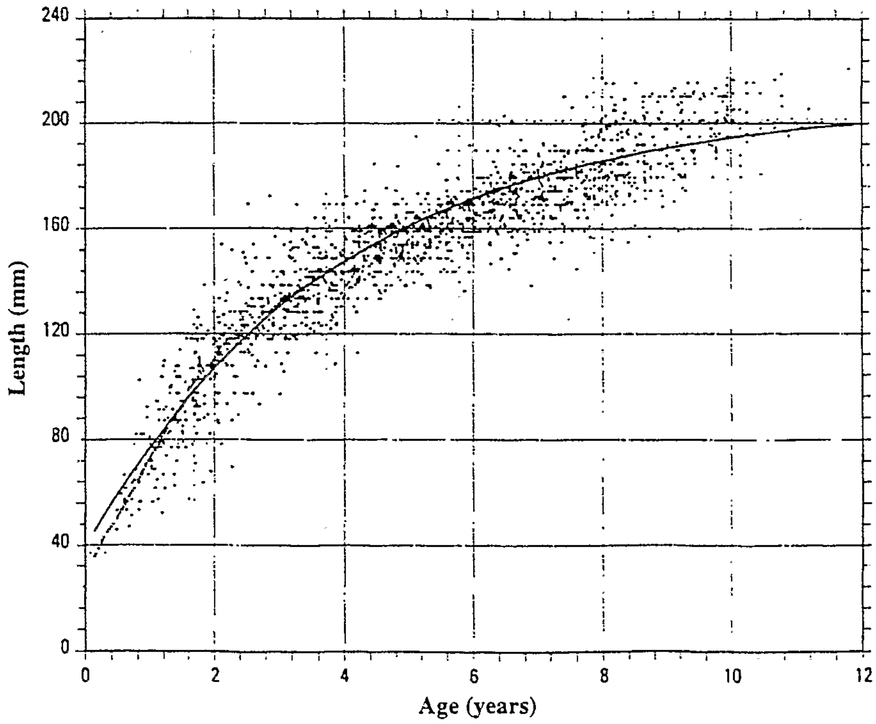

Figure 2: Theoretical pearl-oyster growth rate using the von Bertalanffy model

Table 5: Comparison of the sizes of oysters observed at Takapoto with theoretical sizes

Age of pearl oysters (years)	Mean length (mm)	
	As observed and std. deviation	As calculated
0.5	40	49.0
1	63 ± 8	67.5
2	102 ± 13	100.0
3	129 ± 12	124.0
4	145 ± 11	143.5
5	156 ± 12	158.0
6	166 ± 10	169.0
7	175 ±10	177.5
8	185 ± 11	184.0
9	193 ± 12	189.0
10	200 ± 9	192.5

Production

The growth and biomass data obtained from this stock can be used to calculate annual production. Natural recruitment and mortality were not, however, taken into consideration in the following calculation and production is estimated as at a constant stock size.

Production from the Takapoto stock is thought to be approximately 620 mt of biomass, from which can be inferred a production/biomass ratio of 0.35, higher than that which the species' life span and mortality would seem to suggest.

Mortality

A very high mortality rate occurred in various lagoons in 1985 and Takapoto was particularly affected. According to the local press, farms raising spats and grafted animals suffered losses of 50 to 80 per cent of stock and natural stocks were also hit, to such an extent that in some stations all the tagged oysters died.

Such events had already been observed with this same species in 1969 and then in 1973 in the Red Sea, at Hikueru Lagoon in the Tumaotu archipelago, French Polynesia, in 1971. The Australian pearl oyster, *Pinctada maxima*, also suffered periods of intense mortality from 1967 to 1977. Marine organism deaths can often be attributed to vigorous phytoplancton blooms, as was the case in the Taiaro Lagoon in 1906, Mataiva Lagoon in 1953 and Punaauia Lagoon in 1963, but no similar phenomenon has been observed in the Red Sea, and there is no proof that an event of this kind occurred at Takapoto.

Studies of dead oysters carried out by IFREMER and EVAAM have revealed identical symptoms to those observed in the Red Sea, but the causes of the disease have not been identified either in the Red Sea or in Australia. The Australians have, however, recently implicated a bacteria of the genus *Vibrio* which is responsible for high mortality rates in oyster-carrying tanks, but its impact in the natural environment has yet to be proved.

It should be added that all the specimens from the five French Polynesian lagoons showed varying degrees of cellular deterioration. This would imply that the stress undergone extended throughout the Tuamotus and indeed perhaps throughout the Territory, but that it led to death only in some lagoons.

In July 1985, the local media announced abnormally high mortality rates in the Takapoto pearl farms, most of which are situated near the village. Observations by ORSTOM divers in October 1985 showed that natural stocks were also affected in the southern part of the lagoon.

The oysters were showing signs of physiological damage, not, however, necessarily leading to death. Fresh observations then revealed that the disease had spread to cover all the southern half of the lagoon in January 1986 and the rest in June 1986.

This was corroborated by observing mortality rates in tagged animals as part of growth studies. High mortality first emerged close to the village in December 1984, and then spread northwards. Every lagoon station had been affected by the first half of 1986.

Inspections showed that minimum natural mortality rates could be broken down into three groups:

☞ the shell was found with the tag. The oyster died a natural death and the record is annotated with an 'M'. Such cases represent minimum natural mortality.

☞ the shell had disappeared but the tag was still present. Two theories can be imagined in such cases: the oyster died a natural death, but the shell disappeared because it moved or crumbled away, for example, or the oyster was taken by a predator (fish, squid) or a fisherman (legally during the diving season or poached). Whatever the reason for its disappearance, the animal is lost to the natural stock and the entry is 'D'; such cases represent minimum total mortality.

☞ where both shell and tag had disappeared, a variety of theories could be entertained: both were taken together, the tag had been destroyed by corrosion or separated from the substrate, or the scientist could not relocate it. So wide is the range of possible theories that this case cannot be included in mortality rate calculations.

If it is considered that the stock when tagging began corresponded to the previous assessment, an attempt can be made to quantify mortality during the experiment by applying calculated coefficients, but without taking into consideration population renewal by natural recruitment.

If minimum natural mortality is taken into consideration, stock numbers would have developed as shown in Table 6.

Almost 3.5 million oysters are thought to have died from natural causes, including 2.5 million during the worst ravages of the disease, in the first half of 1986.

If cases of disappearance are added to the minimum natural mortality figures, it is possible to appraise minimum mortality (see Table 7).

Table 6: Minimum natural mortality on Takapoto Atoll

	April 1983 to January 1986	January to June 1986	June 1986 to June 1987
No*	7,500,000	6,760,947	4,084,596
Minimum nat. mortality	739,053	2,513,904	162,447
Mortality rate	0.039	1.107	0.039
Percentage	9.85%	37.18%	3.97%

No* = number of pearl oysters at the beginning of the period under consideration

Table 7: Minimum total mortality on Takapoto atoll

	Avril 1983 to January 1986	January to June 1986	June 1986 to June 1987
No	7,500,000	3,376,713	2,100,768
Nt*	4,393,953	2,733,626	592,295
Minimum tot. mortality	4,123,287	1,275,945	1,505,473
Mortality rate	0.201	1.130	0.700
Percentage	54.90%	37.78%	71.60%

Nt* = number of pearl oysters at the end of the period under consideration

Population size differences between the end of one period and the beginning of the following may be explained by the fact that specimens for which neither shell nor tag were found were included in the appraisals.

At the end of this mortality study, it emerged that minimum natural mortality is very low if the dramatic circumstances which occurred in late 1985 and early 1986, during which almost 40 per cent of the population probably perished, are excluded.

On the other hand, mortality due to predation (natural or fishing) was very high except during the peak period of natural mortality and more particularly after that period. The nature of the data collected does not make it possible to quantify either type of predation, but since fishing activity was clearly responsible, this is a very touchy stock management issue.

It clearly raises the problem of defining fishing quotas and controlling poaching, especially when such harvesting is damaging a stock which has already been considerably weakened by natural causes.

Tuamotu pearling in legend and literature

Pearls live in legend, literature — *Excerpts from an article by Fran Dieudonne, published in* Pacific Magazine, *May/June 1994, pp. 52–53.*

> *'Much of the mystery and myth of these burning atolls were concerned with the quest of pearls – hundreds of thousands (throughout history) had perished to fetch them from the depths of the sea.'*
>
> Frederick O'Brien, *Atolls of the Sun*, 1922

Moody, mysterious and mesmerising; that is how some of the early South Sea writers described the 'Paumotu atolls', more commonly known as the Tuamotu Archipelago of French Polynesia.

Frederick O'Brien, Louis Becke and S.W. Powell were three writers who found their way to this overpowering place that laid such a lasting claim on them and their readers.

In O'Brien's day, the atolls were decrepit, a place of rickety, salt-stained lean-tos and corroded sheds. O'Brien writes about an era that no longer exists and of the rough, hazardous and often overly romanticised life of the pearl-fisher:

'On many maps, these atolls are yet inscribed as the Pearl Islands. About their glorious lagoons was a mist of obscurity and wonder for centuries.

There were accounts of divers who sank deeper in the sea than science said was possible, and the priceless pearl plundered or bought for a drinking song'.

He described the prostration of Paumotuan pearl divers who went to depths of 148 feet and who then 'continued to pursue their fascinating and near-fatal employment until, by afternoon, a heap of heavy, darkish bivalves lay in the canoe'.

> *There are moments in a diver's life;*
> *One, when a beggar, he prepares to plunge;*
> *Then, when a prince, he rises with his pearl.*

The unknown poet of the above envisioned the diver's emotions, but it is Powell in his *South Sea Diary*, 1912, who best paints a word-picture of the stampede that followed when a diver announced his possession of a pearl by holding his hand aloft as his canoe or boat came into the shallows:

'Buyers stampede toward him. Their rush is like the rush of animals; they flounder; they barge carelessly into one another in their eagerness not to be late. Their voices assassinate the stillness. They bid; disputing, barking, contesting like beasts.'

An ancient chinese poet described pearls as the 'hidden soul of the oyster.'But, the life of the pearl diver was less than poetic. The procedure was primitive. A diver, after taking a few deep breaths, would descend several fathoms. O'Brien, in describing the dive, wrote:

'He had about his waist a *pareu* of calico, blue with large white flowers, and a sharp sailor's knife at the belt. Around his neck was a sack of coconut fiber.

'He forced himself down with astonishing speed and in 20 seconds, he was at his goal. He moved